

SWOT Analysis for Using BIM for Infrastructure across the Whole Lifecycle of Transportation Projects

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ABSTRACT: The transportation infrastructure plays an important role in affecting the development of the national economy, which has developed rapidly in recent years. However, the cost of transportation projects is huge, and the traditional project process management causes a waste of time and resources. Building Information Modelling (BIM) is widely used in the building industry, but also can be used in the whole life cycle of transportation projects to improve the project efficiency. SWOT analysis is an important tool to assist the development of enterprises by analyzing their strengths, weaknesses, opportunities and challenges. In this paper the authors use SWOT analysis to investigate the BIM application across the whole lifecycle of transportation projects and to provide advice for their future development accordingly. The result shows that although BIM can save time, money and resources, facilitate management and information exchange, and has a wide application prospect, there are still some technical and normative problems. Interaction between different specialties, information aggregation and fusion, and new regulations to deal with new technologies are all the problems to be resolved.

1 INTRODUCTION

The transportation industry is an important prerequisite for the economic and social development of a country [1]. Logistics and transportation promote economic development, but also bring challenges [2,3]. The congestion problem brought by urbanization construction also poses challenges for transportation construction. China's population base is large and its growth rate is fast. Urbanization construction is also being rapidly promoted. The construction of transportation projects plays an auxiliary role in the national economy. In the process of developing transportation projects, the government should not only consider the economic benefits it brings, but also the requirements of its sustainable development [4]. Therefore, a more effective method is needed to plan and manage the whole life cycle of transportation projects [1]. In recent years, the construction industry is gradually promoting the use of BIM [5]. BIM for infrastructure can help stakeholders better understand the design items, estimate and control costs, facilitate construction planning and monitoring, and improve project quality [6]. Transportation project planning and management through BIM can optimize the traditional project operation mode.

Transportation projects are expensive and difficult to manage. Normally, they are constructed by private or state-owned companies and monitored by the government. These companies and government should not only serve the people, but also have profitable income. Therefore, it is necessary to adopt strategic methods to make important decisions as to whether a certain approach is desirable. SWOT is one such method [7]. This method of analysis is derived from business management. It was first proposed by a professor of Management Economics at University of San Francisco, USA [9].

As an analytical system summarized by Stanford Research [8], it is suitable for profitable units such as enterprises [9], because it is intuitive, flexible, and can produce practical outputs. SWOT

is the abbreviation for strength, weakness, opportunities and threats, which can be defined as below [7,8,9]:

- Strengths——favorable properties/features that can enhance its competition.
- Weaknesses——unfavorable properties/features that can hinder its development.
- Opportunities——external factors that can promote its development.
- Threats——external factors that prevent from achieving the intended results.

In this paper the authors introduce the application of BIM for infrastructure across the whole life cycle of a project (design, construction, operation and maintenance phases) based on a comprehensive literature review. The reason for why BIM can reduce project cost, time and resource consumption is explained. SWOT is used to analyze the results of BIM application in the whole lifecycle transportation projects. The analysis provides suggestions for the development of transportation infrastructure.

2 METHODOLOGY

Three steps were adopted in conducting the literature reviews for this paper: 1) determining the database, 2) determining the keywords, 3) screening and classifying information.

2.1 Determine the database

In order to ensure the reliability of academic contents, relevant academic journal articles and international conference articles were reviewed. In order to ensure the timeliness of the academic content, literature from 2000 to the present was considered. Table 1 shows the database used for this article.

Table 1. Examined journals categorized by scope

Category	Journal title	Publisher
Construction	Journal of Building Engineering	Elsevier
	Archives of Civil and Mechanical Engineering	Elsevier
	Journal of Building Engineering	Elsevier
	International Journal of Construction Education and Research	Elsevier
	Automation in Construction	Elsevier
Built environment	Construction and Building Materials	Elsevier
	Journal of Computing in Civil Engineering	ASCE
	Building and Environment	Elsevier
	Build Simulation	Tsinghua University
	Building Research & Information	Taylor & Francis
energy	Procedia Engineering	Elsevier
	Energy and Buildings	Elsevier
	Procedia – Social and Behavioral Sciences	Elsevier
	Archives of Civil and Mechanical Engineering	Elsevier
Civil and mechanical engineering	Cities	Elsevier
	Advanced Engineering Informatics	Elsevier
Informatics technology	International Conference on Computing in Civil and Building Engineering	ICCCBE
	International Workshop on Computing in Civil Engineering	ASCE
	International Construction Specialty Conference	ICSC
	IFAC-Papers On Line	Elsevier

Sustainable development Management	Sustainable Cities and Society. Process Safety Progress European Journal of Operational Research	Elsevier Elsevier Elsevier
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2.2 Determine the search keywords.

The purpose of determining keywords was to find the relevant articles that can address the main question of this study. Table 2 lists the questions to be discussed and the keywords corresponding to them.

Table 2. Questions and keywords

Questions	Keywords
What is the life cycle of infrastructure	Infrastructure; LCA
What is the goal of infrastructure development	Infrastructure; development
What functions can BIM achieve	BIM
What functions of BIM are needed in infrastructure	BIM for infrastructure
What does infrastructure management include	Infrastructure; management
How is BIM used in the whole life cycle of infrastructure	BIM for infrastructure; Life cycle
What are the advantages/benefits of using BIM in infrastructure	BIM for infrastructure; Advantages/benefits
What are the disadvantages/challenges of using BIM in infrastructure	BIM for infrastructure; Disadvantages/challenges
What are the application examples of BIM in infrastructure	BIM for infrastructure; Case study
What is SWOT analysis	SWOT analysis
What are the advantages of SWOT analysis method	SWOT analysis

2.3 Information screening and classification

Once the databases were determined, a keyword search could be performed in the database. Search results were filtered through abstracts and conclusions of articles. The relevant articles in this paper were classified and stored for information screening.

3 APPLICATION OF BIM FOR INFRASTRUCTURE

BIM can build 3D models, 4D/5D models, even nD models, so the resulting information models can better visualize the details of the project, better control the time and cost of the project in the whole project cycle, and improve the quality of the project. It can help manage different project phases more effectively from planning and design to construction and maintenance [1,5].

3.1 In the design stage

Planning in the design stage not only needs to meet the requirements of various standards and specifications, but also needs to reduce the cost as much as possible, avoid risks and reduce construction time to improve efficiency. BIM for infrastructure can be used to create, manage, and share design models, coordinate between different disciplines and reduce design-time spatial collisions [1,10]. Cheng et al. [11] pointed out that BIM spatial visualization can be used in pipeline design of foundation projects to avoid pipeline overlap and to adjust the spatial relationship between different models, so as to avoid design errors. One of the most important benefits of BIM is clash detection, which can prevent possible major design errors at the beginning of the design and eliminate time and cost overruns caused by rework [11]. Visualization of design is also convenient for explaining design concepts and key points to owners, and for owners to make intuitive comparisons between various designs options. At this stage, it can be used in conjunction with (Geographic Information System) GIS technology to facilitate better integration of human and geographical environment of the project [12].

BIM for infrastructure can be used to calculate the amount of work, such as the amount of materials used in construction, the amount of earth filled and excavated, and the use of machinery and equipment. It will also ensure the efficient use of resources by reducing the energy consumption. Moreover, it does not need a lot of time to recalculate the amount of work when the design changes, which can save designers' energy and time in the early design stage. It is also important to determine the construction process in the early design stage. Smooth and reasonable construction process can improve the utilization rate of mechanical equipment, improve work efficiency, reduce time and cost [13]. It can better cope with the current promotion of green sustainable development in China and prevent waste of resources.

3.2 *In the construction stage*

BIM for infrastructure provides better visualization operation to optimize the details of construction work, improve the accessibility and operability in the construction phase, enhance the coordination of various departments [1], and improve the quality of the project. It can greatly prevent the incorrect construction caused by inaccurate transmission of information from the designers to the constructors. When errors occur, BIM can also be used to remedy them. For example, if incorrect reinforcement is used in a beam, the original design can be replaced by the incorrect reinforcement method. The structure connected with the beam can be checked by BIM, and the joint mode of reinforcement can be adjusted to reduce material waste.

In the construction phase, the critical components that need to be managed effectively include process, material and goods, cost, machinery and equipment, risk and quality control. Although these factors have been considered in the design stage, there will be many uncertainties in the construction phase, so it is necessary to monitor the site in real time and adjust the construction plan according to the real conditions [14]. BIM for infrastructure can use the 4D model to monitor the construction process in real time, judge whether the time and expenditure exceed the budget, adjust the budget and time as necessary, so that the project can be completed on time, and on budget. According to the site conditions at different construction stages, the possible risks can be also assessment through the models. BIM for infrastructure can be used to plan the space of construction site and separate the construction scope of equipment from that of constructors, so as to avoid potential safety hazards to constructors caused by improper mechanical operation [14].

3.3 *In operating and maintenance stage*

The data collected during the design phase and the data updated during the construction phase of the infrastructure can be stored by BIM and used in the operation and maintenance phase of the infrastructure [11]. BIM for infrastructure can use data organization and integration to carry out detailed geometric design [15]. According to the geometric model data and data sensors, it can check whether the structural deformation exceeds the specified range and whether it needs maintenance or reconstruction. Thus will maintain structural reliability, security and serviceability [16]. BIM for infrastructure can also carry out structural analysis and post-repair analysis of infrastructure with a certain service life according to the load conditions, so as to improve the feasibility of the repair scheme [15].

4 SWOT ANALYSIS OF USING BIM FOR INFRASTRUCTURE

4.1 *SWOT analysis*

In order to better utilize BIM in the whole life cycle of a transportation project, it is necessary to clearly identify its strengths, weaknesses, opportunities, and threats. The following SWOT analysis is conducted based on the existing literatures related to BIM for infrastructure.

4.2 *Strengths*

In early design, BIM for infrastructure can avoid collision problems that may occur when combining various design models, so as to avoid risks as early as possible. Research by Kim et al. [17] and Hu et al. [18] confirms that BIM for infrastructure can combine geometric information, timetables and historical data to help plan and manage projects, to evaluate and analyze their

security, and to identify and reduce risks quickly. According to the research of Golovina et al. [19], the use of BIM for infrastructure can avoid the workspace conflict between staff and heavy equipment, thus reduce the risk of construction stage. BIM for infrastructure can also be used to estimate construction time and cost. By comparing the as-built conditions with the design model, it can also optimize the management during construction and operation and maintenance, and reduce the waste of time and cost. Based on the empirical study of Lu et al. [20], BIM for infrastructure can reduce the construction cost by 8.61%. Visualization model can show the appearance and details of the project, which is convenient for comparison and selection between different schemes. It will also improve the overall comfort of the building, more in line with social and economic benefits [21]. In the whole life cycle of the project, there is a need for efficient communication and collaboration among multiple parties. The visualization and information exchange produced by BIM can facilitate and help maintain effective communication platform [22]. Using BIM and Life Cycle Assessment (LCA) to analyze the whole life cycle of the project, the design scheme with the least energy consumption and the least emission of greenhouse gases or harmful substances can be obtained [23].

4.3 Weaknesses

Usually a huge amount of investment funds are needed for the technology and the necessary training in the early stage [1]. Using BIM for infrastructure at the design stage will result in an additional 45.93% effort [20]. If different parties use different software to development models, there may be problems that the model cannot be interoperable and integrated when summarizing design schemes [24,25]. Eadie et al. [26] also agreed that when different departments use new methods and software to model or organize information, problems such as incompatibility of models or lack of information will arise in the process of summarizing or communicating. It is hard for different disciplines to get very accurate information from the models produced by other incompatible software, and thus also difficult for them to check the clashes between different design components [27]. BIM for infrastructure can't store all the data of the whole project, for example, some information (eg. material properties and functions) makes it necessary to set up other external database for storage [28]. In such case, it will be necessary to establish multiple databases to ensure information integrity, which makes it more difficult for information management and search.

4.4 Opportunities

Currently, there is a trend of moving towards smart city. Various models produced by BIM for infrastructure can be combined and managed to help with integrated management of the city [7]. With the assistance of big data, BIM for infrastructure can be used to store information and help built smart cities [29]. The models can also be used as reference to improve the efficiency of maintenance or transformation programs, save resources and contribute to sustainable development. BIM and other surveying and mapping tools can be used to manage and analyze existing for infrastructure that have not be modeled before. If the facility has become old enough that affects its use or has potential safety hazards, BIM can be used to reconstruct a more energy-efficient and environmental-friendly facility. [30]. Using BIM in the whole life cycle of infrastructure projects can help facilitate a more environmental-friendly city [31].

4.5 Threats

When using BIM together with other technologies in the whole life cycle of projects, it will produce a huge amount of digital data [32]. This requires an integrated system to preserve, manage, search, and use the information, but such system is hard to establish. To build an integrated city, it is necessary to use BIM and other information collection and processing tools together. This also brings incompatibility issues. In order to achieve collaboration among different divisions, information models are shared with each other, which might bring challenges in the copyright and information loss [33]. New standards and regulations need to be established to resolve these challenges.

5 CONCLUSION

In this paper the authors use SWOT analysis to analyze the application of BIM in the whole cycle of transportation projects. Through the analysis of the advantages, disadvantages, opportunities and challenges of the current BIM application, the issues that need to be addressed in the development of transportation infrastructure are summarized. BIM plays an important role in reducing energy consumption, saving time and cost. It can also provide convenience in management (including construction, operation and maintenance), and provide technical support for future urban intellectualization. However, it will require a great amount of time and cost spent on the training of staff. Moreover, there may be incompatibility issues resulting from the information exchange between different specialties. New standards and regulations are also needed to better cope with the adoption of new technology.

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